Translation of the attached sheet (Japanese text portions only)
Background Art Information

Patent No./Publication Inventor(s)/Author(s) Date etc
Jpn. Pat. Appln. KOKAI Publications No. 2001-143416 and No. 8-212733 *Concise Explanation The inventions of these publications have problems in that the clocking accuracy is not high.
Jpn. Pat. Appln. KOKAI Publication No. 1-208777 *Concise Explanation The invention of this publication has problems in that the time for writing a reference servo pattern is inevitably long.
Jpn. Pat. Appln. KOKAI Publication No. 2001-243733 *Concise Explanation The invention of this publication has problems in that a master disc is hard to process with high accuracy.
Prior Applications of Inventors or of Kabushiki Kaisha Toshiba (Assignee) Application No. Toshiba Reference Country Agent memo
Inventor(s) Signature & Date

Patent engineer's comment on inventor's information or patent engineer's information
No Particular comments to make. *
Checked by Dated
Toshiba Reference Japanese Agent's Ref sheet

平成15年5月14日

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（株）東芝ﾃﾞｼﾞﾀﾙﾒﾃﾞｨｱﾈｯﾄﾜｰｸ社
知的財産部 知財技術担当
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芳賀

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＜添付資料＞

3VG032564－USA－A	米国出願明細書
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以上

TITLE OF THE INVENTION

Magnetic Disk Drive Apparatus Having A Self-Servo Writing System
and
Method for Writing Servo Pattern Therein

CROSS-REFERENCE TO RELATED APPLICATIONS

[001] This application claims the benefit of priority from Japanese Patent Applications No. 2001-84325, filed on March 23, 2001, and No. 2001-275592, filed September 11, 2001. Each of these applications is hereby incorporated by reference in its entirety.

BACKGROUND OF THE INVENTION

Field of the Invention

[002] The invention relates to magnetic disk drive apparatus having a servo system and methods for writing servo data therein. More particularly, it relates to apparatus and methods for performing self-servo writing based on reference servo data (servo patterns) being preliminary written in a disk medium.

Description of the Related Art

[003] Conventionally, in order to write and read data on and from a target track on a recording surface of a data storage disk medium (hereinafter refers to as a "disk"), a magnetic disk drive apparatus, such as a hard disk drive apparatus, (hereinafter simply refers to as a "disk drive") includes a servo system for moving and positioning the magnetic head elements onto the target track. The servo system includes a servo controller

for controlling a drive a rotary actuator so as to carry the head elements onto a target track by using reference servo data (servo patterns) on a recording surface of a disk. The reference servo patterns are preliminary provided at servo areas on a recording surface of a disk at a predetermined interval. The servo controller includes a micro processor (CPU) for mainly controlling a disk drive and a voice coil motor (VCM) driver for driving a rotary actuator under a control of CPU. The reference servo patterns (data) include track address signals and servo burst signals. Track address signals detect each of track positions and the servo burst signals detect a position in a particular track.

[004] Conventionally, these reference servo patterns are written in servo areas in each of recording surfaces of a disk by using a specialized instrument for servo track writer. Thus, it needs for manufacturing of a disk drive to include a process for writing reference servo patterns in both sides of a disk.

[005] The specialized servo track writer instrument includes a head positioning control system (hereinafter referred to as a "positioner") in order to drive a rotary actuator in a disk drive before the servo writing process. In order to write servo patterns onto a disk, the disk drive itself is temporary fixed in the specialized servo writer instrument so as to synchronize each movement of the positioner and a rotary actuator in a disk drive. Thus, the positioner decides a head position by controlling a moving amount of a rotary actuator as a preceding process for servo pattern writing operation. The positioner includes a positioning controller for inputting a target position as an absolute position.

[006] The operation for writing servo patterns (data) is performed through the head element of a disk drive. When a target position is inputted, the positioning controller seeks an error between a present position of the positioner and a target position. Based on a remaining distance to the target position, the positioning controller calculates an operation amount C(z) for driving a motor in the positioner by a rotation angle M(s). Thus, the positioner is moved by an amount P(s).

[007] The positioner further includes an encoder for measuring a feedback moving amount E(s) to the positioning controller as an absolute position of the positioner. During the feedback operation, the moving amount E(s) may happen to be affected by seeking noises. The positioner further includes a pushpin that is coupled to a rotary actuator so as to move the actuator by an amount R(s) in accordance with a moving amount P(s) of the pushpin. Based on the moving amount R(s) of the rotary actuator, a head slider moves by an amount H(s). Thus, an actual position for writing servo pattern is determined. Even after when the servo pattern writing position is determined, there is some possibility for the servo pattern writing position to be influenced by vibrations of a spindle motor (SPM) of the disk drive. This causes to produce an error for the servo pattern writing position.

[008] Further, the servo truck writer instrument includes a clock head for writing clock pattern during a rotation of a disk by a SPM. The servo truck writer instrument decides a write timing of a servo data along a rotational direction of a disk by reading the clock pattern through the clock head. The servo truck writer instrument executes the servo pattern writing operation by using the writing head element based on the clock timing detected by the clock head. Thus, when the head positioning operation is

completed, the servo truck writer instrument instructs to a writing head element to write servo patterns in a target track.

[009] When the servo pattern writing operation for one circle of a track has completed, the positioner moves to a next position of target truck circle. By repeating the same servo pattern writing operations on the succeeding positions of target truck circle, the servo patterns are written on one surface of a disk. Since a disk has two surfaces, the same operation for writing the servo patterns is performed on other surface of a disk.

[009] In order to accurately write the servo patterns, as explained above, it needs to measure the relative position between a head and a disk surface. However, even if a position of the positioner is controlled in a high accuracy, it does not mean to reduce the relative position error between a head and a disk surface because the disk is a rotating body connected to a spindle motor (SPM). Thus, in order to improve the accuracy of the servo pattern writing, it needs to accurately follow the head position in responding to position variations due to the SPM.

[010] Since the operation for writing servo patterns on a disk is performed by removing a top cover of a disk drive, i.e., both of a disk surface and magnetic head elements are exposed, the servo patterns writing operation must be performed in a clean room environment.

[011] Recent increase of recording density in a disk surface, i.e., a higher track pitch, increases the number of tracks for writing the servo patterns. As a result, an operation time for writing the servo patterns per one disk drive is also extremely increased. So far, it takes more than twenty

minutes for writing the servo patterns per one disk drive including a disk that are formed more than ten thousand tracks in one surface. Thus, the servo writer instrument is occupied by one disk drive until completing the servo pattern writing operation on both surfaces of a disk. Recently, much more increase of the track density is expected. Under these circumstances, it needs to install an increased number of the servo writer instrument in an enlarged clean room environment.

[012] When the servo pattern writing operations on both surfaces of a disk have completed, the disk drive is removed from the servo writer instrument, the disk drive is covered with a top cover and is brought to a functional verification process for the disk drive by attaching a circuit board module.

[013] However, the conventional apparatus and method for writing servo patterns by using a specialized servo truck writer instrument have serious shortcomings, in particular relating to a writing accuracy of the servo patterns and to a manufacturing cost.

[014] As explained above, a conventional servo truck writer instrument drives a rotary actuator based on a movement of the positioner. In this time, a relative error between a present position of the positioner and a feedback of a target position is supplied to the position controller as a control amount. As a result, when the positioner reaches to a position of a target truck, it has been assumed that a writing head element on the rotary actuator also reached to the position of the target truck. Then the position controller calculates an amount of the operation in order to reduce the relative error between them. However, it essentially needs to seek the

relative position between the head element and the disk in order to write the servo patterns with a sufficient accuracy. Thus, even if the position of the positioner is controlled with a sufficient accuracy, it is not necessarily to reduce an error of the relative position between the head element and the disk. Especially, a disk has always caused position changes since the disk is a rotating device attached to a SPM. Thus, it is inevitable to correctly follow the head position against the changes of the disk position due to the SPM in order to increase the accuracy for writing the servo patterns.

[015] Furthermore, recently, in order to increase the storage density of a disk, a higher track density is required. Thus, the numbers of tracks for writing the servo patterns are also extremely increased. As a result, the servo pattern writing time for a disk drive is also increased. So far, more than one thousand tracks are formed on both surfaces of a disk. And it usually takes more than twenty minutes for completing the writing of servo patterns to the whole surfaces of a disk side. In near future, much more increases of the track density is also expected.

[016] The servo writer instrument is occupied by one disk drive until completing the writing the servo patterns on the whole surfaces of a disk. Consequently, in accompanying to the above situation, it is required to increase the number of the servo writer instrument. Furthermore, the conventional servo writer instrument must be used in a clean room, a site expansion for the clean room environment is also required in connection with the increase of the servo writer instruments. The necessity for increasing the production number of the disk drive also affects much more serious problems. Thus, the conventional method for using a servo data writer instrument always holds the problem of the manufacture cost.

[017] To overcome the above and other disadvantages of the prior art, apparatus and methods consistent with the present invention performs self-servo writing operation without using a special servo writer in order to increase the accuracy of the write positions and the write timing of servo data and also to reduce the disk manufacturing costs.

SUMMARY OF THE INVENTION

[018] An embodiment consistent with the present invention relates to a magnetic disk drive apparatus that can determine an appropriate servo pattern writing position by measuring a relative position error between a head and a disk surface facing the head The magnetic disk drive apparatus further write servo patterns over both surfaces of the disk by alternately operating two pair of head elements without recognizing time phase differences due to calculation of position error. The magnetic disk drive apparatus comprises a disk medium including a first and a second surfaces, each of the surfaces having a plurality of recording tracks and a plurality of preliminary recorded reference servo data, each of the recording tracks having a certain track width; a first pair of head elements facing close to the first surface for writing a first servo data and/or reading the reference servo data; a second pair of head elements being located symmetrically to the first head elements about the disk medium so as to face close to the second surface for writing a second servo data and/or reading the reference servo data; a head positioner for alternately determining the first and second head position for data writing on the respective surfaces by calculating a first relative position between the second head elements and the second surface based on the reference servo data or the second servo data read by the second

head elements, and by calculating a second relative position between the first head elements and the first surface based on the reference servo data or the first servo data read by the first head elements; a head mover for alternately carrying the first or second head elements to the data writing position on the respective surfaces determined by the head positioner; and a servo data writing controller for controlling the respective servo data writing on the respective data writing positions in the respective surfaces by the respective head elements.

[019] Another embodiment consistent with the present invention relates to a magnetic disk drive apparatus having a self-servo data writing system that utilizes reference servo data and reference clock pattern preliminary recorded in predetermined areas of a disk. More practically, the disk applicable to the invention includes predetermined areas in which reference servo data for determining a write position in a radius direction and reference clock patterns for determining write timing in a rotational direction. The magnetic disk apparatus, comprises: a disk medium including a first and a second data recording surfaces, each surfaces having reference data area in which reference servo data for determining a writing position along a radius direction and reference clock patterns for determining a writing timing along a rotational direction are preliminary recorded; a first and second pair of magnetic head elements for performing data read/write operations on the respective surfaces of the disk medium; and a controller for controlling servo data writing operation in a predetermined area of the respective surfaces by using the reference servo data and the reference clock pattern read by the magnetic head elements facing to the respective surfaces during a servo writing process; wherein: the controller includes: a positioning controller for determining a writing position of the servo data

along a radius direction of the disk medium by using the reference servo data; and a writing controller for determining a writing timing of the servo data along a rotational direction of the disk medium by using the reference clock patterns.

[020] A further embodiment consistent with the present invention relates to a magnetic disk drive apparatus includes a pair of read and write heads that are arranges along a radius direction of a disk so as to accurately read the preliminary recorded servo patterns during determination of write position of servo data. The magnetic disk drive apparatus determines a write position of servo data by reading a burst signal that is arranged every 1/2 pitch in the preliminary recorded reference servo pattern on a first face of a disk through a first read head, and writes a new burst signal on the second surface by a second write head at 1/4 pith outer position that oppositely corresponds to the position of the burst signal read by the first read head. Alternately, the first write head write a new burst signal on the first surface by reading the reference servo pattern preliminary recorded on the second surface at 1/4 pith outer position that oppositely corresponds to the position of the burst signal read by the second read head.

[021] An additional embodiment consistent with the present invention relates to a method for writing servo data in a magnetic disk drive apparatus including a disk medium including a first and a second surfaces, each of the surfaces having a plurality of recording tracks and a plurality of preliminary recorded reference servo data, each of the recording tracks having a certain track width; a first pair of head elements facing close to the first surface for writing servo data and reading the reference servo data; and a second pair of head elements being located symmetrically to the first head

elements about the disk medium so as to face close to the second surface for writing servo data and reading the reference servo data. The method comprises writing a first servo data on the first face by the first head elements; reading the reference servo data or the first written servo data by the first head elements; writing a second servo data on the second face by the second head elements; reading the reference servo data or the second written servo data by the second head elements; calculating a first relative position between the second head elements and the second surface based on the reference servo data or the second servo data read by the second head elements; determining the first head position for data writing on the first surfaces; calculating a second relative position between the first head elements and the first surface based on the reference servo data or the first servo data read by the first head elements; determining the second head position for data writing on the second surfaces; and alternately carrying the first or second head elements to the determined data writing position on the respective surfaces.

[022] Yet another embodiment consistent with the present invention relates to a method for writing servo data in a magnetic disk drive apparatus including a disk medium including a first and a second data recording surfaces, each surfaces having reference data area in which reference servo data for determining a writing position along a radius direction and reference clock patterns for determining a writing timing along a rotational direction are preliminary recorded and a first and second pair of magnetic head elements for performing data read/write operations on the respective surfaces of the disk medium; the method comprising: reading the reference servo data and the reference clock pattern by the first read head facing the first surface of the disk medium; determining a writing position in the

second surface by using the reference servo data read through the first read head; determining a writing timing of the second write head by using the reference clock pattern read through the first read head; and writing the reference servo data and the reference clock pattern on the second surface of the disk medium by the second write head.

BRIEF DESCRIPTION OF THE DRAWINGS

[023] The accompanying drawings, which are incorporated in and constitute part of this specification, illustrate various embodiments and/or features of the invention and together with the description, serve to explain the invention. Wherever possible, the same reference numbers will be used throughout the drawings to the same or the like parts. In the drawings:

[024] Figure 1 is a block diagram of an exemplary configuration for self-servo writing system in which methods and apparatus consistent with the present invention may be implemented.

[025] Figure 2 is a block diagram for explaining basic theories of the self-servo writing system consistent with the present invention.

[026] Figure 3 is a diagram of an exemplary relationship between read/write head elements and a preliminary embedded reference servo pattern used in the methods and apparatus consistent with the present invention.

[027] Figure 4 is a diagram of an exemplary relationship between a read head and a write head used in the methods and apparatus consistent with the present invention.

[028] Figures 5A and 5B explain write positions in a disk in accordance with the methods and apparatus consistent with the present invention

a flowchart of an exemplary technique for self-writing servo data onto a disk medium in accordance with methods and apparatus consistent with the present invention.

[029] Figure 6 is a block diagram of an exemplary configuration of a positioner for determining write positions of servo patterns in a disk drive apparatus consistent with the present invention.

[030] Figure 7 is a diagram for explaining time delay of writing judgment in the magnetic disk apparatus consistent with the present invention;

[031] Figure 8 is a diagram showing servo pattern writing positions by both head pairs in the magnetic disk apparatus consistent with the present invention;

[032] Figure 9 is a section view of the disk for explaining alternately postscript write operations in the apparatus consistent with the present invention;

[033] Figure 10 is a diagram showing servo patterns and clock patterns used in anther embodiment of the magnetic disk apparatus consistent with the present invention;

[034] Figures 11A-11C explains servo write operations in the anther embodiment of the magnetic disk apparatus consistent with the present invention; [035] Figure 12 is a flow chart explaining servo write operations in the anther embodiment of the magnetic disk apparatus consistent with the present invention

DETAILED DESCRIPTION

[036] Reference will now be made in detail to the exemplary embodiments of the invention, examples of which are illustrated in the

accompanying drawings. Figure 1 is a block diagram of an exemplary configuration for a servo system in a magnetic disk drive apparatus 100 in accordance with methods and apparatus consistent with the invention. The magnetic disk drive apparatus 100 includes a magnetic recording disk medium 10 of which surfaces are coated with magnetic material, a spindle motor (SPM) 20 for rotating the disk 10, and a rotary actuator 30 for driving a head slider 40 along a radius direction of the disk 10. The actuator 30 includes a suspension arm for holding the head slider 40 and a voice coil motor (VCM) 50 for rotating the head slider 40. The head slider 40 supports a pair of magnetic head elements 1H, i.e., a write head 1W for writing data into the disk 10 and a read head 1R for reading data from the disk 10.

[037] The disk 10 used for a small sized magnetic disk apparatus employing a sector servo system, such as, an HDD of 2.5 inches, includes a multiplicity of concentric circular tracks on both data recording surfaces of the disk 10. Thus, as shown in Figure 2, a practical disk drive apparatus includes another pair of head elements 2H (i.e., a write head 2W and a read head 2R) facing a backside surface of the disk 10 for writing and reading data.

[038] During operation of the disk drive apparatus 100, the SPM 20 rotates the disk 10 in a high-speed counterclockwise. The pair of the head elements 1H (1W, 1R) is floating close to a surface of the rotating disk. For implementing to the disk drive apparatus 100 consistent with the invention, in each pair of the head elements 1H and 2H, a write head and a read head are arranged in parallel along a radius direction of the disk 10 on the slider 40. The slider 40 moves closely on a surface of the disk 10 along generally a radius direction of the disk by rotation of the rotary actuator 30. The rotary

actuator 30 moves heads and determines a head position on a target track (TP) of the disks 10 under a servo control of a microprocessor (CPU).

[039] The disk drive apparatus 100 further includes a pre-amplifier 5, a read/write (R/W) channel 6, a disk controller (HDC) 7, a CPU 8, a memory 9, and a motor driver 60. The pre-amplifier 5 amplifies reproduced signals read by the head 1R from the disk 10. Further, pre-amplifier 5 includes a write amplifier for converting write data to write currents. Read/write channel 6 decodes data from the reproduced signals by performing PRML signal processing. R/W channel 6 includes a servo data reproducing circuit. Thus, the decoded data includes servo data. Further R/W channel 6 executes, for example, RLL coding process for write data. HDC 12 executes transfer controls of read and write data as an interface unit between the disk drive apparatus 100 and a host system, such as a personal computer or another digital devices. Motor driver 60 includes a VCM driver 61 for driving VCM 50 and a SPM driver 62 for driving SPM 20.

[040] The CPU 8 is a main controller of the disk drive apparatus 100. Further, CPU 8 is included a servo controller for realizing a self-servo writing system of an embodiment consistent with the present invention. Thus, the servo controller includes CPU 8, the servo data reproducing circuit in R/W channel 6 and a VCM driver 62. The servo controller performs positioning controls of magnetic head and self-servo data write operation by reproducing reference servo data (pattern) and reference clock pattern that have preliminary recoded in the disk 1 0. CPU 8 controls input value, i.e., control voltage of VCM driver 61 for driving rotary actuator 30 through VCM 50. Memory 9 includes a RAM, a ROM and a flush EEPROM for storing

control program for the self-servo writing operation and other various control data.

[041] Each of recording surfaces of disk 10 includes a predetermined number of reference servo areas 110 and a multiplicity of tracks 112. In each of servo areas 110, servo patterns is recorded at a predetermined distance in a circumference direction of the disk during a preliminary servo writing process by using a special servo writer instrument. By using servo areas 110 as references, the multiplicity of tracks 112 is formed in concentric circles. A plurality of reference servo areas 112 and a plurality of data sectors 114 are alternately provided at a certain distance. Thus, as a pretreatment process, reference servo patterns and reference clock patterns are preliminary recorded in servo areas on at least one surface of disk 10. The reference servo patterns (SP) include track address codes for detecting each of track positions and servo burst signals, i.e., position error signals for detecting a position in each of tracks. The clock patterns (CP) are recorded between the reference servo patterns for determining write timings in a rotational direction RD of the disk 10.

[042] With reference to Figure 2, a basic principle of postscript of servo patterns implementing to disk drive apparatus consistent with the invention will be is explained. Basically, in this embodiment, the servo controller controls to additionally write servo pattern at outer tracks of disk 10 by reading reference servo patterns recorded at inner tracks of disk 10. As mentioned above, magnetic disk apparatus 100 includes two pair of magnetic head elements 1H and 2H that are arranged so as to overlap up and down on both surfaces of disk 10. First pair of head elements 1H includes a write head 1W and a read head 1R facing an upper surface of disk 10. Second pair of

head elements 2H includes a write head 2W and a read head 2R facing under surface of disk 10.

[043] Since reference servo patterns are preliminary embedded at inner tracks of disk 10, read head 1R in the head pair 1H reads the reference servo patterns. A position controller 71 detects an appropriate position of read head 1R against to tracks on the upper surface of disk 10. With reference to the detected appropriate position of read head 1R, position controller 71 moves and positions the write head 2W, for example, in 1/4 pitch part perimeter of disk 10. In accordance with instructions form a servo write controller 72 in the servo controller, write head 2W writes the servo patterns at the target position.

[044] By preliminary recording the servo area 110 over the corresponding several ten to hundreds tracks on the upper surface of disk, it becomes possible to additionally write the servo patterns over the substantially same number of tracks in the under surface of disk 10. When the servo patterns are written on both surfaces over the substantially same number of tracks, the servo write operation is alternately performed on both surfaces of disk10 by turns. Thus, in this embodiment, it is necessary to preliminarily write reference servo patterns 110 at least one surface of disk 10. However, the preliminary write operation of the servo patterns can be finished by only several ten seconds, since it is written only over several ten to hundreds tracks. Of cause, it is also possible to preliminary write the reference servo patterns 110 on both surfaces of disk 10.

[045] During the operation of servo patterns write, it needs to unite clock timing in bit unit between the preliminary servo patterns and the

postscript servo patterns. It is possible to set up so that the write timing may acquire from reference burst signals. The write timing is explained later.

[046] In postscript operation of servo patterns, it can realizable a high accuracy of the writing by considering as to a positional relation between a write head and a read head in the same head pair. Now reference to Figures 3 and 4, the positional relation of read/write heads for implementing to the embodiment consistent with the invention is explained. As described above, as a practical, read operation and postscript operation of servo patterns are performed by alternately changing the head pairs. Here, in order to clarify the position relation of both heads, for convenience, write head and read head in the same head pair is shown.

[047] Figure 3 illustrates that a preliminarily embedded reference servo pattern 300 is comprised address codes 301 and burst patterns 302. The address code 301 includes a plurality of codes corresponding to each of tracks. Each code has information for indicating a position and a number of a particular track. The burst pattern 302 is comprised of a plurality of burst signals A-D positioning on or middle portion of each track. The positioning controller identifies a particular track based on each code read by the read head 1R and calculates an appropriate position in a particular track based on a output ratio of each burst signal. In Figure 3, the reference servo pattern 300 is supposed to be written by successively moving the head pair 1H in 1/2 pitch right direction under the following order.

→A → move → code → D→ move → B → move → code → C→ move → A→

[048] If this servo pattern postscript operation is applied to a conventional magnetic disk apparatus in which a read head and a write head

are arranged in an overlapped position along a radius direction, a problem of an accuracy regarding position of the postscript of servo pattern will arise. Thus, when A burst signal is additionally written over the right end track of the reference servo pattern 300 by using the vertically arranged head pair, both of write head and read head are positioned at the far right of the reference servo pattern. As a result, read head can detect only partial parts of address code and burst pattern on the track. This causes to reduce a signal output and induces error of the output signal. Thus, it becomes impossible to detect exact track position or track number. Further it becomes impossible to detect a position in a track based on the signal output ratio. This originates in arranging giant magneto-resistive head (GMR) that is most popularly used now in disk drive apparatus, so that the relative position of write head and read head arranged on slider to be as close as possible in order to reduce the amount of position compensation. Thus, the conventional head elements are generally disposed in a direction of the circumference of disk 10.

[049] To avoid this disadvantage, as shown in Figures 1 and 4, the pair of magnetic head elements 1W and 1R is arranged in parallel with a predetermined distance along a radius direction of the disk 10.uin. In this embodiment consistent with the invention, the GMR write head 1W and read head 1R are arranged so as to separate at least more than 1 track pitch. According to this, even if when the postscript of A burst signal arranged over the right end track 316 shown in Figure 3 is performed, read head 1R can read reference servo pattern 300 with sufficient accuracy. Thus, write head 1W become possible to perform postscript operation of servo patterns at an appropriate position. As a result, the embodiment consistent with the invention can improve the accuracy of servo pattern postscript, since all the four burst patterns A to D are fully used for positioning the head elements.

[050] Moreover, in the conventional disk apparatus, the reference servo pattern 300 can be recorded only at middle circumferences on disk, because the write head and read head elements are arranged along a rotary actuator direction so as to locate on the same track when both heads located in the middle circumferences on disk. On the contrary, according to the head composition in the embodiment consistent with the invention, it becomes possible to record the reference servo patterns 300 at an inner circumferences on disk 10 or an outer circumferences on disk 10, as shown in Figures 5A and 5B.

[051] With reference to Figure 6, alternately positioning operations for the servo pattern postscripts according to each head pair is explained. Figure 6 illustrates servo pattern postscript positioning mechanism by, for example, a write head 1W in disk drive apparatus 100.

[052] First, as explained above, an appropriate relative position relation between write head 1W and the disk 10 is sought, based on reference servo pattern 300 read from an upper surface of the disk 10. Micro-controller 8 searches for an error the target position (offset position) of write head 1W to the upper surface of disk 10 and the relative position, and calculates the operational amount for moving and positioning head to a target position (TP). The target position (TP) as an offset position of write head 1W is inputted into positioning controller 71. Positioning controller 71 searches the position error (relative position) of write head 1W and disk 10, and calculates an amount C (z) of operations according to the remaining distance to this target position (TP). The calculated C(z) is supplied to actuator unit 80 for moving

head elements. The actuator unit 80 includes a VCM 50, a rotary actuator 30 and a slider 40.

[053] The operation amount C(z) is converted to drive currents and supplied to VCM 50. In this case, such as power disturbances may act to the operation amount C (z). In response to the operation amount C (z), VCM 50 rotates by the rotation amount (angle) V (s). By the rotation angle V (s) of VCM 50, the rotary actuator 30 moves the slider 40 by a moving amount R (s). Based on the movement amount R (s), the slider 40 moves by a movement amount H (s). Since the write head 1W is attached on the slider 40, a write-in position of servo pattern is determined. The determined write-in position of servo pattern is detected by a position detector 90 as a detection amount E (s). The detection amount E (s) is supplied to the position controller 71 as a feedback.

[054] As illustrated in Figure 6, various disturbances, such as acceleration disturbances (power disturbances) D generated by rotations and vibrations of disk 10, SMP vibration servo patterns M, or observation noises N applied to decoded signals or the circuit, or are applied to the actual head positioning system of magnetic disk apparatus 100. As a result, the relative position relation between disk 10 and the position of write head 1W is always also varied. However, in the embodiment consistent with the invention, the position detector 90 feedbacks the detection amount E (s) to the position controller 71, the improvement in positioning accuracy is realized. The detection amount E (s) includes SMP vibration M which mainly affects as an error generating factor of head position. Positioning controller 71 is preliminarily designed so as to sustain or reduce such disturbances.

[055] Figure 7 shows the processing times required for the postscript operations of servo patterns in this embodiment consistent with the invention. When all operations by the 1st head pair have completed, servo pattern write-in operation by the 2nd head pair 2H is started. Thus, as shown in Figure 7, the operations by the 1st head pair includes a servo signal read time Tr, position error calculation time Tc, and servo data write-in judgment time Tj. Consequently, the it will arise a time phase difference between the servo patterns used positioning by the 1st head pair 1H and the write-in servo patterns by the 2nd head pair 2H, at least due to the position error calculation time Tc, and the servo data write-in judgment time Tj. The delay time is around 15-20 microseconds. However, even if the phase difference arises in the servo patterns corresponding to each heads, it does not become a problem since each of surfaces facing the first head pair 1H and the second head pair 2H are respectively independent from the others. In essence, it should keep a regular interval for the servo sector intervals on each surfaces of a disk.

[056] On the contrary, if both of head positioning operation and servo pattern writing operation are performed by using the first head pair 1H only, it becomes difficult to keep the constant servo sector interval since the phase difference will occur in the same surface of a disk side. In order to keep a constant servo sector interval by using the first head pair 1H only, after passing through the processing time required for positioning operation by the read head 1R, it needs to write-in dummy servo patterns corresponding to the phase difference by the write head 1W. Further, after writing the dummy servo patterns, it needs to carry out positioning operation by read head 1R. After then, actual servo patterns are written by write head 1W. Such operations are very complicated. Moreover, since such

dummy servo patterns is not required for a magnetic disk apparatus, they must be eliminated after completing the servo patterns writing operations. Thus, it takes excessive operation time.

[057] According to the embodiment consistent with the invention, as illustrated in Figure 8, the first head pair 1H and the second head pair 2H alternately performs servo patterns read operation and servo patterns writing operations. Thus, the transcript of servo patterns is independently performed on each surface sides of a disk.
For example, after when the first read 1R completes the reading operation of the servo pattern 1RSP1 at a reference position on the upper surface, the second write head alternately perform the servo pattern writing operation on the lower surface of the disk 10 during servo pattern write operation capable time PT which begins after a judgment delay time DTj.

[058] Thus, first, a head positioning of read head 1R is performed based on reference servo pattern 1RSP1 written in the upper surface of disk 10, and a servo pattern postscript operation by write head 2W is performed on the lower surface of the disk. Next, head positioning is performed by read head 2R based on servo pattern already written the backside surface on disk 10, and a servo pattern postscript operation of by write head 1W is performed on the upper surface of disk 10. Thus, both of head pairs perform alternately reading and writing operations. Consequently, even if time phase differences occur between the servo patterns used for head positioning and the recorded servo patterns, it does not become a problem. Moreover, it does not need to generate excessive operations, such as dummy servo patterns. Basically, the servo pattern writing operation on an opposite surface of the disk 10 may carry out at any time as long as the judgment delay time DTj.

Figure 8 illustrates that the servo pattern writing operations are alternately performed by the write head 1W and the write which are preliminarily shifted in a position of 1/2 servo sector.

[059] Figure 9 illustrates the alternately postscript operation viewed from a section of disk 10. Here, in case of postscript operation by write head 1W and 2W, each write heads are shifted in 1/4 pitch interval with each other along a radius direction so as to realize the postscript of 1/2 pitch servo pattern on both surfaces of the disk 10. In Figure, RP1H indicates a reference position of the first head pair 1H and RP2H shows a reference position of the second head pair 2H.

[060] With reference to Figures 10-12, another embodiment consistent with the invention is explained. In this embodiment, as illustrated in Figure 10, disk 10 includes preliminarily recorded reference servo patterns (SP) and reference clock patterns (CP) on one surface of the disk 10. Here, as shown in Figure 11, reference servo pattern (SP) and reference clock pattern (CP) are alternately recorded on an upper surface 1S of disk 10 in a rotational direction RD of the disk 10.

[061] As shown in Figure 12, firstly, servo controller 72 reads out reference servo signals from the corresponding reference servo pattern (SP) through the first read head 1R (step S1). Based on the reproduced servo data from the read out reference servo signals a head position of the first read head 1R is judged (step S2). Next, by using the position of the first read head 1R as reference, positioning control of the second write head 2W is carried out in a target position on the corresponding undersurface 2S of disk 10. In practical, as shown in Figure 2, the second write head 2W is positioned by

moving a rotary actuator in 1/4 pitch outer direction of the disk. Namely, as shown in Figure 9, the servo controller 72 seeks a relative position relation (RP1H, RP2H) between the write head 2W on the back surface 2S and the upper surface 1S based on reference servo pattern SP read from the upper surface 1S of disk 10. Then, the controller 72 controls positioning of the write head 2W on a target position by calculating an error of the corresponding relative position relation (RP1H, RP2H).

[062] On the other hand, servo controller 72 determines accurate timing of writing position along the rotation direction RD of disk 10 based on reference clock patterns read out by read head 1R (step S4). In accordance with the write-in timing, servo controller 72 executes writing of reference servo pattern SP on a target position in the back surface of the disk 10 by the second write head 2W (step S5). In practically, as shown in Figure 11B, reference servo patterns SP are copied on the undersurface 2S of disk10. In this case, the copied reference servo patterns SP are written in a counter position to the recorded reference clock patterns CP on the upper surface 1S.

[063] Further, servo controller 72 writes in reference clock patterns CP between servo patterns of back surface 2S of disk 10 by the second write head 2W. (step S6). Thus, as shown in Figure 11C, reference clock patterns CP are copied on the undersurface 2S of disk10. In this case, reference clock patterns CP are copied at the counter positions of the recorded reference servo patterns SP on the upper surface 1S.

[064] When reference servo patterns SP and reference clock patterns CP are copied on both surfaces of disk 1 0 (step S7, YES), the servo controller performs alternately writing the servo patterns SP and clock patterns CP on

both surfaces of disk 10 (step S8). That is, based on the reference servo patterns SP and reference clock patterns CP read by second read head 2R, servo patterns SP and clock patterns CP are written by first write head 1W on upper surface 1S of disk10. Moreover, servo patterns SP and clock patterns CP are written on the under surface 2S by second write head 2W, based on reference servo patterns SP and reference clock patterns CP which are read by first read head 1R. Newly written clock patterns CP are used in order to adjust timing in bit unit between the already written servo patterns SP and the postscript servo patterns SP. By using these clock patterns CP, the write positions of servo patterns and clock patterns along the rotation direction RD of disk 10 are determined.

[065] According this embodiment of this self-servo writing method consistent with the invention, it becomes possible to write servo data on both surfaces of disk 10 by the disk drive 100 itself, with preliminarily writing reference servo patterns SP and reference clock patterns CP on several tens to several hundreds tracks of on one surface of disk. The clock patterns CP (including reference patterns) on the disk 10 are overwritten on data sector (user data) on the data tracks.

[066] In this embodiment, it needs to preliminarily write reference servo patterns SP and reference clock patterns CP on several tens to several hundreds tracks before performing self-servo writing operation. However, it takes only several ten seconds to several minutes for writing on a surface per disk. Further according to the self-servo writing method of this embodiment, servo data can be accurately written by the head element in the drive apparatus itself, since the positioning control of write head and setting-up of write timings along the rotation direction are performed by using the

preliminarily recorded reference servo patterns SP and reference clock patterns CP on the disk 10.

[067] According to this embodiment, during the writing operation of servo patterns on the disk, an appropriate write position can be determined based on the indispensable relative position error of head elements and a disk surface, and the servo writing operation can be performed by write timing along the disk rotation direction by using the magnetic heads in the disk drive itself. Thus, it becomes possible to realize a higher accuracy of the servo writing operation.

[068] As explained above, the magnetic disk apparatus 100 and method for writing servo patterns are performed by alternately changing servo patterns reading operation and servo patterns writing operation on both surfaces of the disk based on the preliminarily written reference servo pattern. Thus, the postscript writing operation of servo data can be performed with attaching a body cover on the magnetic disk apparatus 100 under a normal environment without using clean room environment.

[069] Moreover, it can achieve an extensive cost improvement by sharply reducing the number of special servo writer instrument since reference servo patterns 110 are written only in a part of disk 10. Furthermore, it becomes possible to prevent inaccurate servo patterns due to accidental factors from writing in the disk 10 by permitting the servo pattern writing operation only when the relative error between the disk 10 and write head 1W enters within a preliminary set up limit. Thus, it is possible to perform postscript operation of accurate servo patterns only. Furthermore,

since there is no necessity of occupying special servo writer instrument for a long time and the postscript operation itself does not have the necessity of carrying out within clean room, it becomes possible to reduce the manufacture cost.

What is claimed is:

1. Magnetic disk drive apparatus, comprising:

a disk medium having a first and a second surfaces, each including a plurality of recording tracks, each having a certain track width, at least one of the first and a second surfaces including a plurality of preliminarily recorded reference servo data;

a first pair of head elements facing close to the first surface for writing a first servo data and/or reading the reference servo data;

a second pair of head elements being located symmetrically to the first head elements about the disk medium so as to face close to the second surface for writing a second servo data and/or reading the reference servo data;

a head positioner for alternately determining the first and second head position for data writing on the respective surfaces by calculating a first relative position between the second head elements and the second surface based on the reference servo data or the second servo data read by the second head elements, and by calculating a second relative position between the first head elements and the first surface based on the reference servo data or the first servo data read by the first head elements;

a head mover for alternately carrying the first or second head elements to the data writing position on the respective surfaces determined by the head positioner; and

a servo data writing controller for controlling the respective servo data writing on the respective data writing positions in the respective surfaces by the respective head elements.

2. The magnetic disk drive apparatus of claim 1, wherein:

the first pair of head elements includes a first write head for writing the first servo data, and a first read head for reading the reference servo data or the first servo data;

the second pair of head elements includes a second write head for writing the second servo data, and a second read head for reading the reference servo data or the second servo data;

the head positioner alternately determines the data writing positions on each of the first and second surfaces by calculating a first relative position between the second read head and the second face based on the reference servo data or the second servo data read by the second read head, and by calculating a second relative position between the first read head and the first face based on the reference servo data or the first servo data read by the first read head.

3. The magnetic disk drive apparatus of claim 2, wherein:

each of the first and second read heads is located at an inner position along a radius direction of the disk so as to apart from each of the first and second write heads by at least more than the track width during operation;

the head positioner successively determines the data writing position of the respective write heads at an outer position along the radius direction of the disk.

4. The magnetic disk drive apparatus of claim 2, wherein:

each of the first and second read heads is located at an outer position along a radius direction of the disk so as to apart from each of the first and second write heads by at least more than the track width during operation;

the head positioner successively determines the data writing position of the respective write heads at an inner position along the radius direction of the disk.

5. The magnetic disk drive apparatus of claim 1, wherein:

the servo data writing controller prohibits the servo data writing operation by the first or second head elements when the first or second relative position calculated by the head positioner excesses a predetermined value.

6. Magnetic disk drive apparatus, comprising:

a disk medium including a first and a second data recording surfaces, at least one of surfaces having reference data area in which reference servo data for determining a writing position along a radius direction and reference clock patterns for determining a writing timing along a rotational direction are preliminarily recorded;

a first and second pair of magnetic head elements for performing data read/write operations on the respective surfaces of the disk medium; and

a controller for controlling servo data writing operation in a predetermined area of the respective surfaces by using the reference servo data and the reference clock pattern read by the magnetic head elements facing to the respective surfaces during a servo writing process; wherein:

the controller includes:

a positioning controller for determining a writing position of the servo data along a radius direction of the disk medium by using the reference servo data; and

a writing controller for determining a writing timing of the servo data along a rotational direction of the disk medium by using the reference clock patterns.

7. The magnetic disk drive apparatus of claim 6, wherein:

the first pair of magnetic head elements facing to the first surface includes a first read head and a first write head, and the second pair of magnetic head elements facing to the second surface includes a second read head and a second write head;

the controller determines the writing position of the second write head by using the reference servo data read through the first read head and the writing timing by using the reference clock pattern read by the first read head; and

the controller performs writing process of the reference servo data and the reference clock patterns on the second surface of the disk medium by the second write head.

8. The magnetic disk drive apparatus of claim 6, wherein:

the first pair of magnetic head elements facing to the first surface includes a first read head and a first write head, and the second pair of magnetic head elements facing to the second surface includes a second read head and a second write head;

the controller performs a copying process of the reference servo data and the reference clock pattern through the second write head by using the reference servo data and the reference clock pattern read by the first read head; and

the controller alternately performs the servo data writing operations on the first and second surfaces of the disk medium by alternately

controlling the first write head and the second write head by using the reference servo data and the reference clock pattern recorded by the copying process.

9. The magnetic disk drive apparatus of claim 6, wherein:

the controller writes the servo data on a surface opposite to a surface having a recorded area of the reference clock pattern.

10. The magnetic disk drive apparatus of claim 6, wherein:

each of the first pair of magnetic head elements includes a read head and a write head mounted on a slider; and

the read head and the write head are located substantially parallel to each other along a radius direction of the disk so as to have a certain distance between them.

11. A method for writing servo data in a magnetic disk drive apparatus including a disk medium including a first and a second surfaces, each of the surfaces having a plurality of recording tracks and a plurality of preliminary recorded reference servo data, each of the recording tracks having a certain track width; a first pair of head elements facing close to the first surface for writing servo data and reading the reference servo data; and a second pair of head elements being located symmetrically to the first head elements about the disk medium so as to face close to the second surface for writing servo data and reading the reference servo data;

the method comprising:

writing a first servo data on the first face by the first head elements;

reading the reference servo data or the first written servo data by the first head elements;

writing a second servo data on the second face by the second head elements;

reading the reference servo data or the second written servo data by the second head elements;

calculating a first relative position between the second head elements and the second surface based on the reference servo data or the second servo data read by the second head elements;

determining the first head position for data writing on the first surfaces;

calculating a second relative position between the first head elements and the first surface based on the reference servo data or the first servo data read by the first head elements;

determining the second head position for data writing on the second surfaces; and

alternately carrying the first or second head elements to the determined data writing position on the respective surfaces.

12. The method for writing servo data of claim 11, further including:

prohibiting the servo data writing operation by the first and second head elements if the calculated relative position excesses a predetermined value.

13. A method for writing servo data in a magnetic disk drive apparatus including a disk medium including a first and a second data recording surfaces, each surfaces having reference data area in which reference servo data for determining a writing position along a radius direction and reference clock patterns for determining a writing timing along a rotational direction are preliminary recorded and a first and second pair of

magnetic head elements for performing data read/write operations on the respective surfaces of the disk medium; the method comprising:

reading the reference servo data and the reference clock pattern by the first read head facing the first surface of the disk medium;

determining a writing position in the second surface by using the reference servo data read through the first read head;

determining a writing timing of the second write head by using the reference clock pattern read through the first read head; and

writing the reference servo data and the reference clock pattern on the second surface of the disk medium by the second write head.

14. The method for writing servo data of claim 13, further comprising:

alternately writing the servo data on each of the first and second surfaces of the disk medium by the second and first write heads, respectively, by using the reference servo data and the reference clock pattern.

15. The method for writing servo data of claim 13, wherein:

the writing the servo data is performed on a surface opposite to a surface having a recorded area of the reference clock pattern.

16. The method for writing servo data of claim 13, wherein:

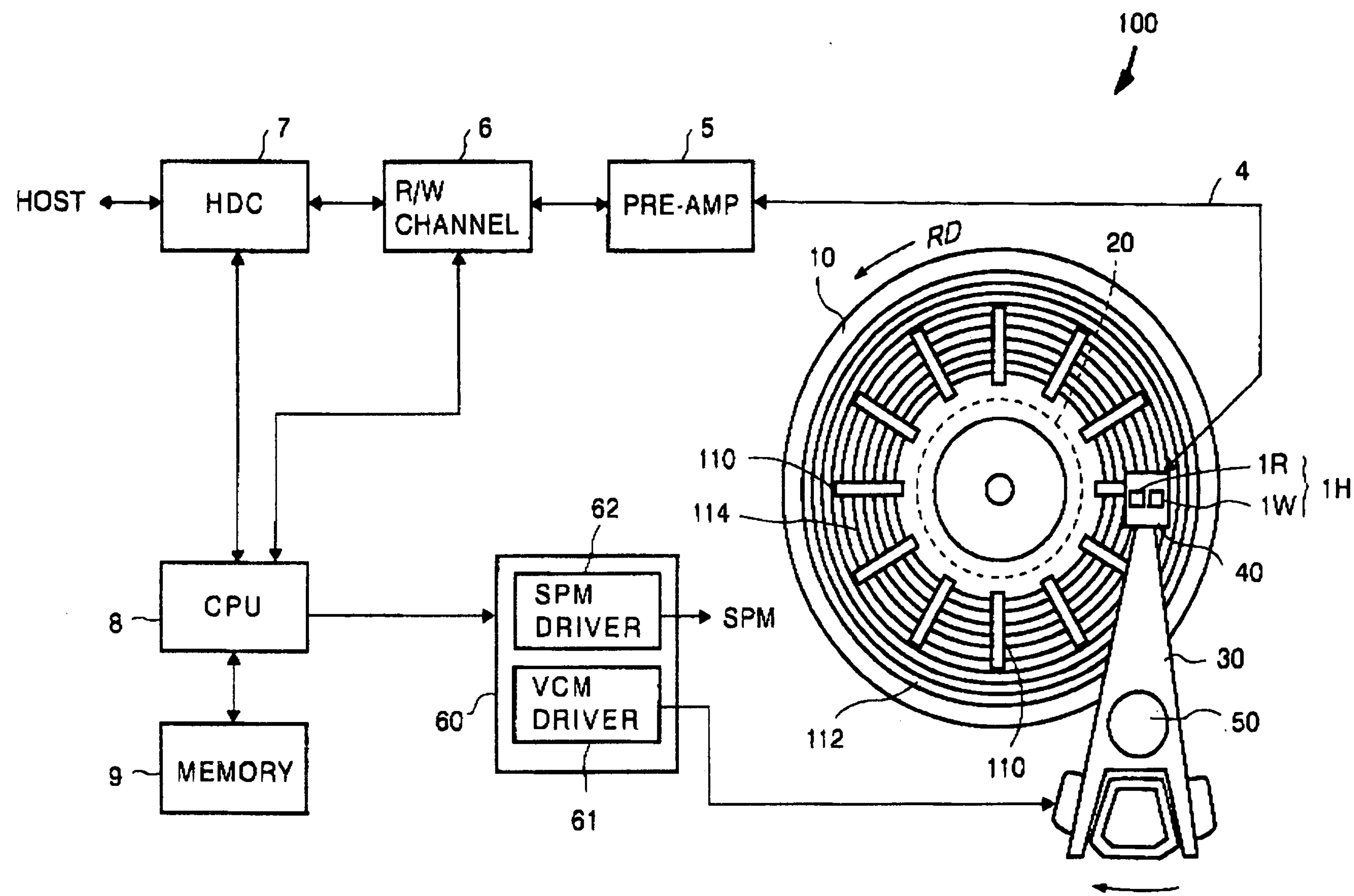
the writing the servo data on the second surface of the disk is performed by using the reference servo data and the reference clock pattern read through the first read head; and

the writing the servo data on the first surface of the disk is performed by using the reference servo data and the reference clock pattern read through the second read head.

ABSTRACT

Magnetic disk drive apparatus and methods for writing servo data in the magnetic disk drive apparatus that can perform a self-servo data writing operation without using a special servo writer instrument in order to increase an accuracy of the servo data writing and to reduce a manufacturing cost of the disk.

The magnetic disk apparatus and methods for writing servo data in the magnetic disk drive apparatus detects a relative position between a magnetic head and a writing surface and performs a feedback the detected relative position for determining the servo data writing position. Based on reference servo pattern that are preliminarily recorded on a portion of at least one surface of the disk, two pair of head elements arranged facing to respective surfaces of the disk alternately performs postscript operation of servo patterns with reducing a relative position error between the head and the disk in order to increase writing accuracy of servo pattern writing operation.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4
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HDC
R/W
CHANNEL
PRE-AMP
RD
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1W
1H
40
62
SPM
DRIVER
SPM
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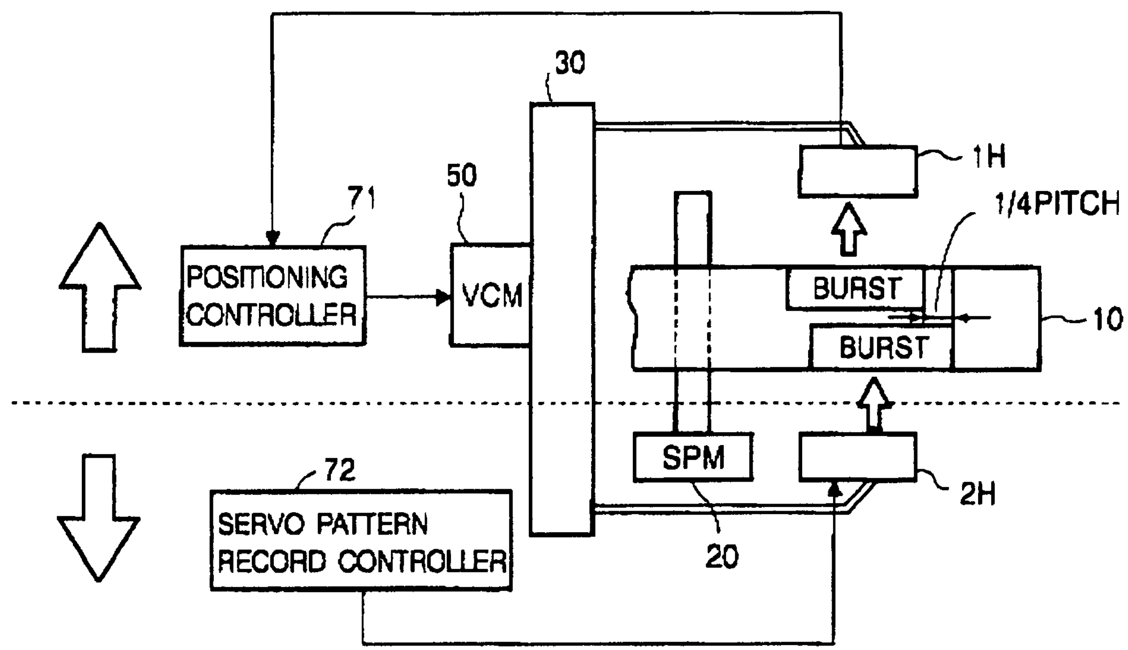
DRIVER
60
30
50
9
MEMORY
61
112
110

FIG.1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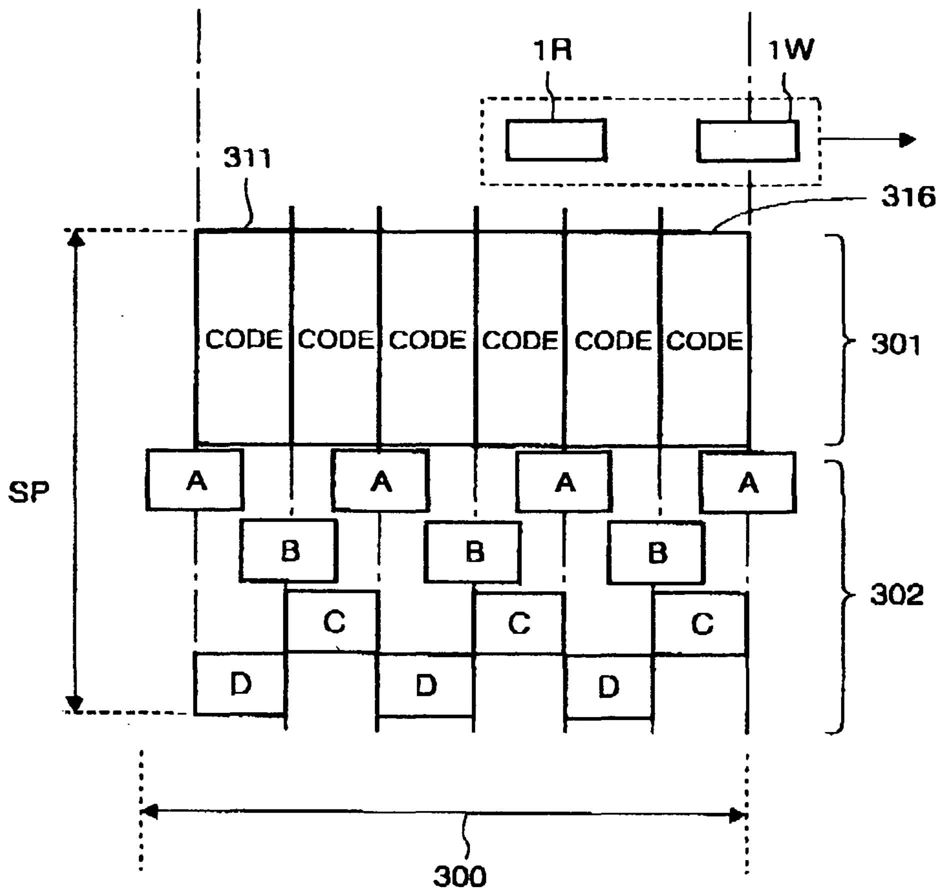
1H
1/4PITCH
71
50
POSITIONING CONTROLLER
VCM
BURST
BURST
10
SPM
2H
72
SERVO PATTERN RECORD CONTROLLER
20

FIG.2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1W
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316
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CODE
CODE
CODE
CODE
CODE
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B
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C
D
D
D
302
300

FIG.3

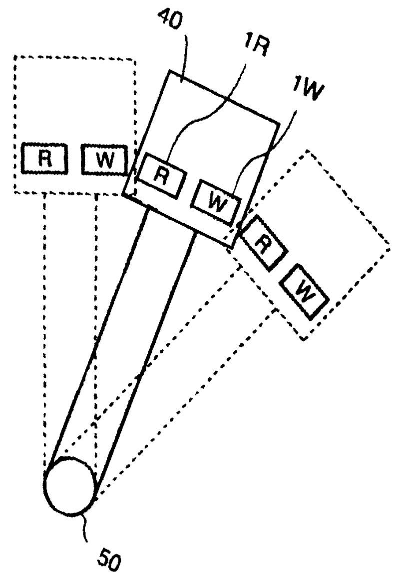


FIG.4

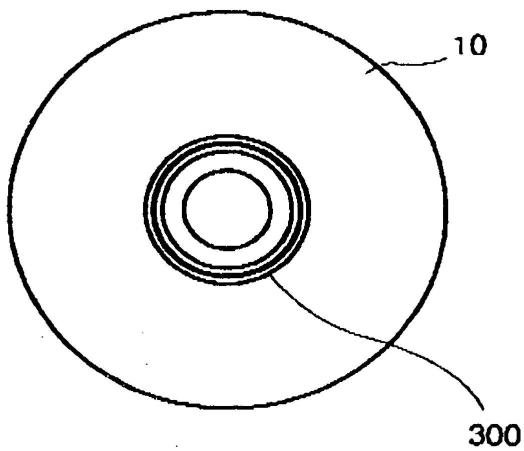


FIG.5A

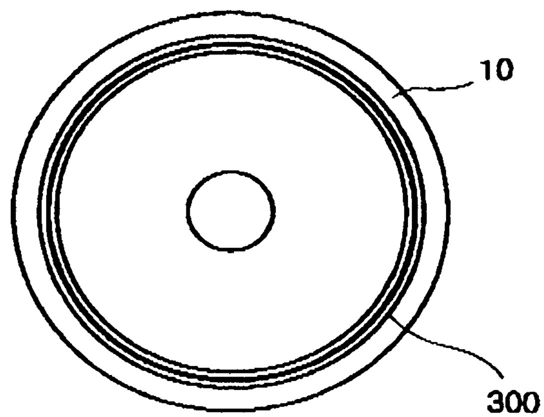


FIG.5B

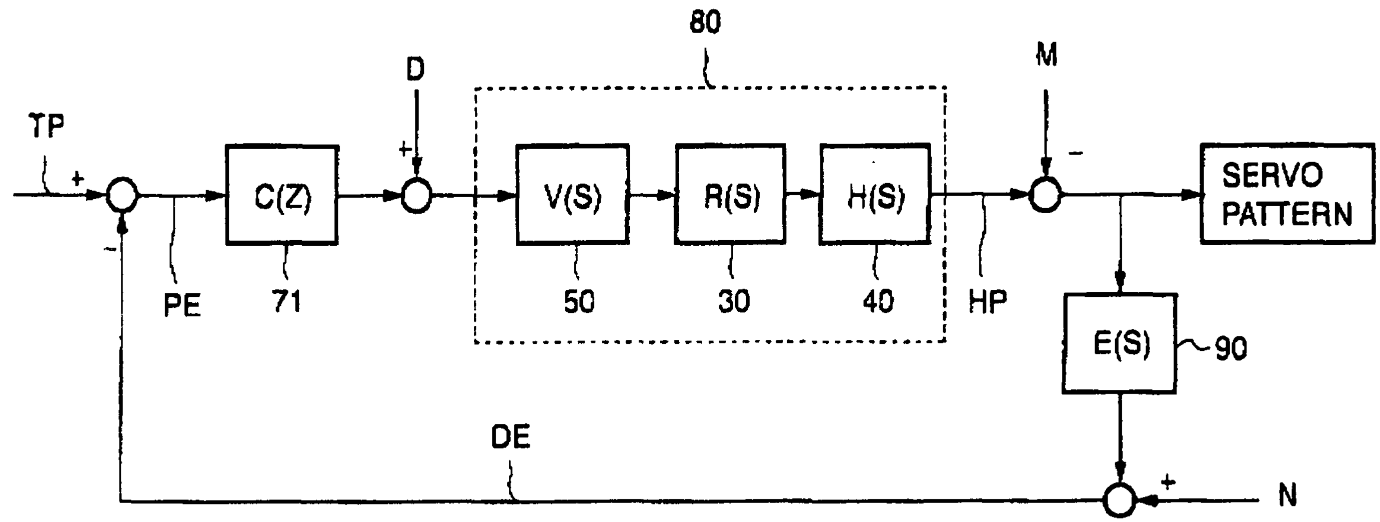
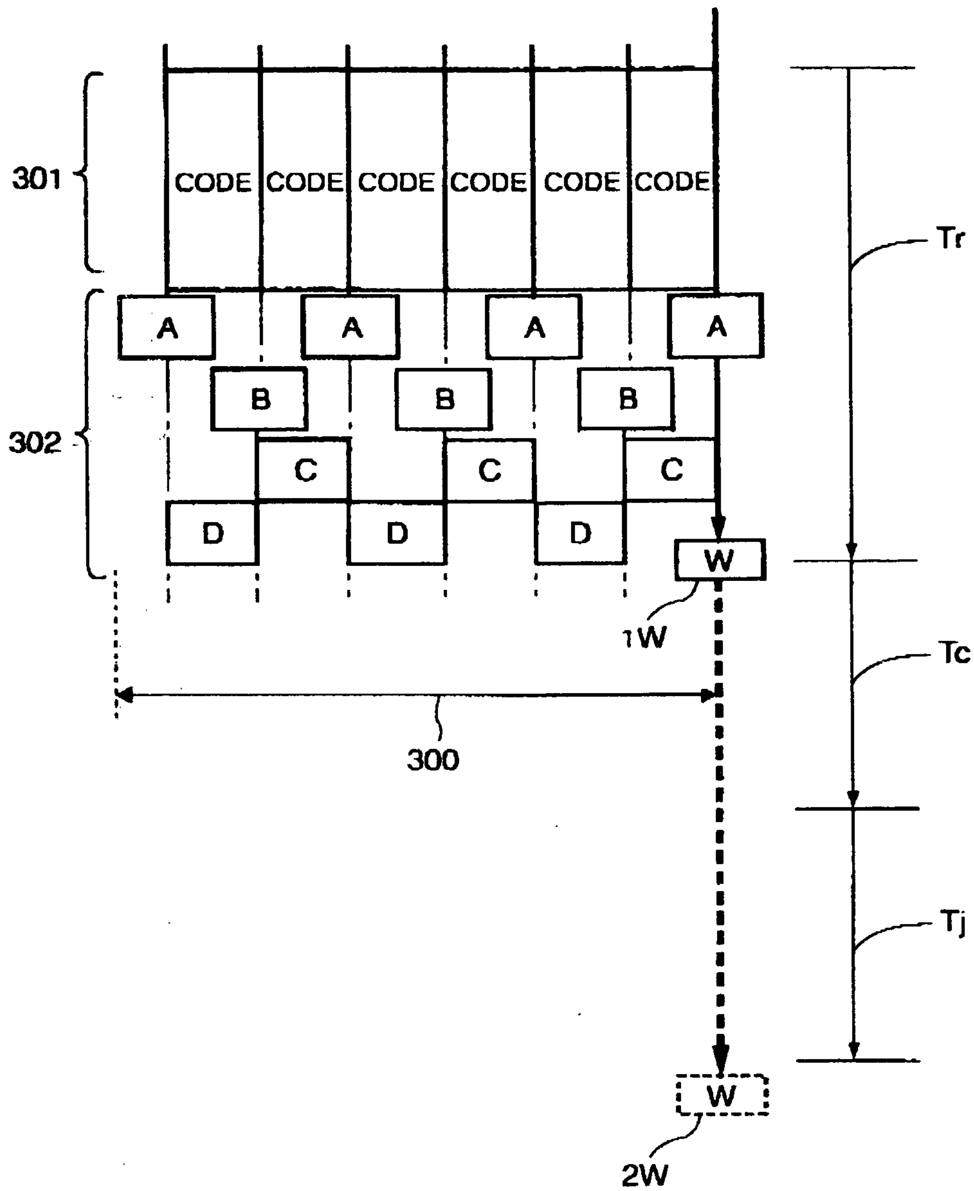


FIG.6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CODE
302
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A
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D
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Tj
W
2W

FIG.7

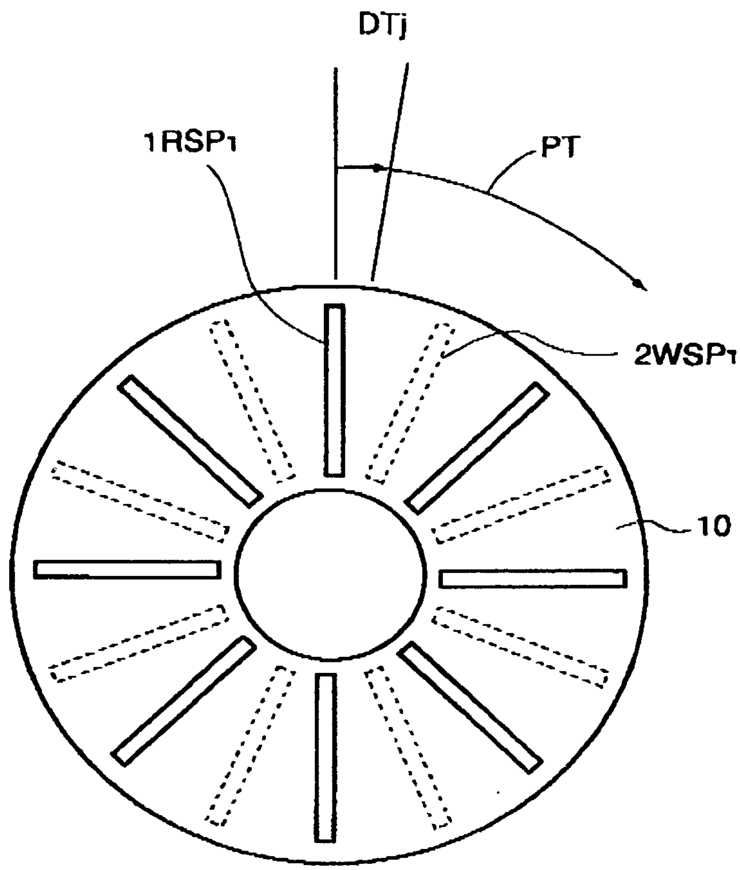

FIG.8

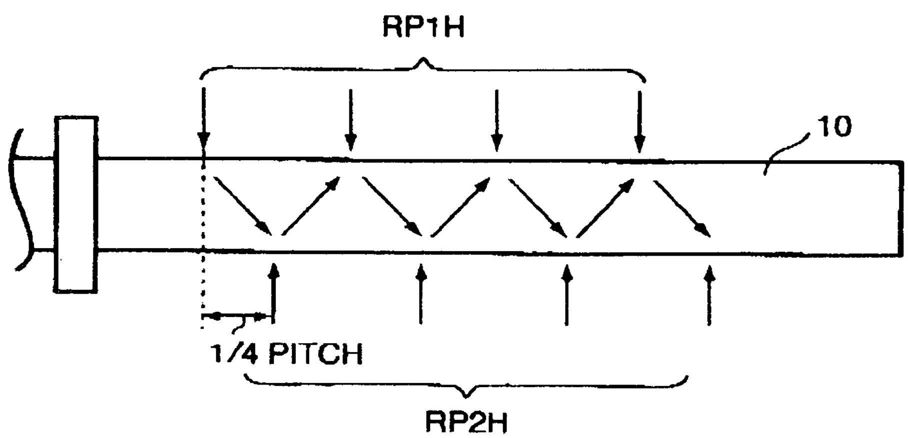

FIG.9

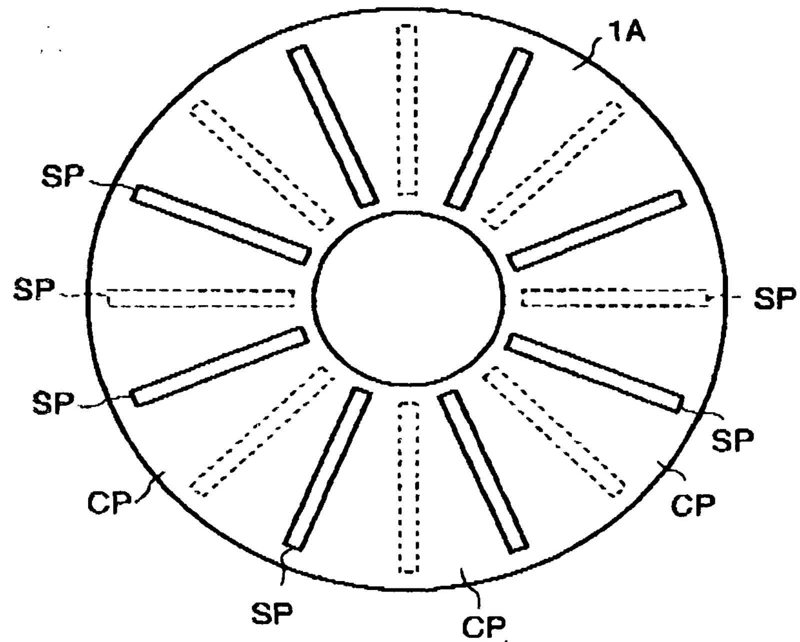

FIG.10

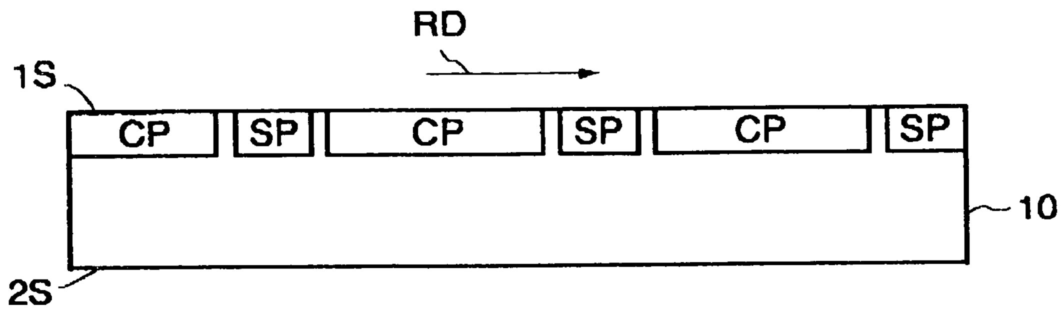

FIG.11A

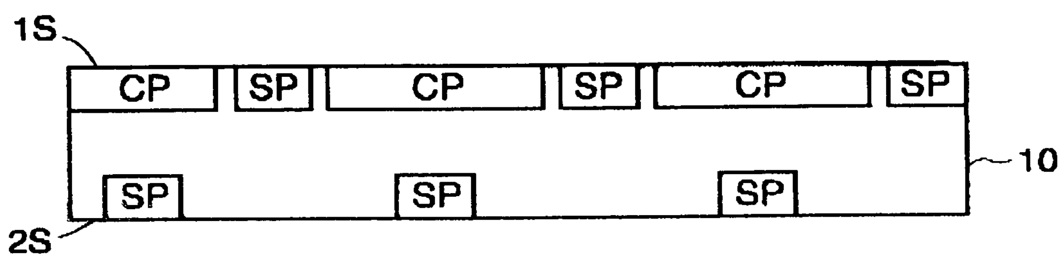

FIG.11B

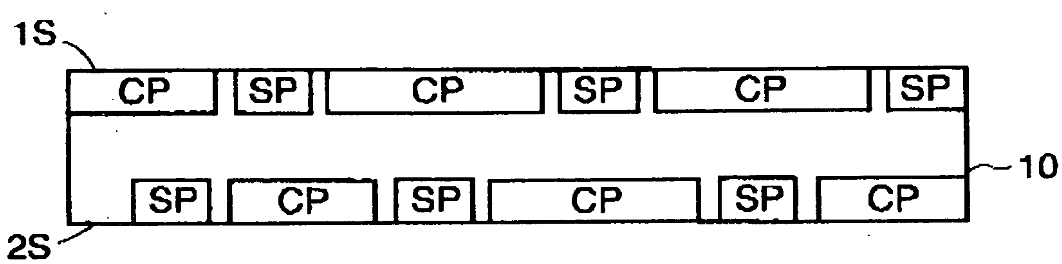

FIG.11C

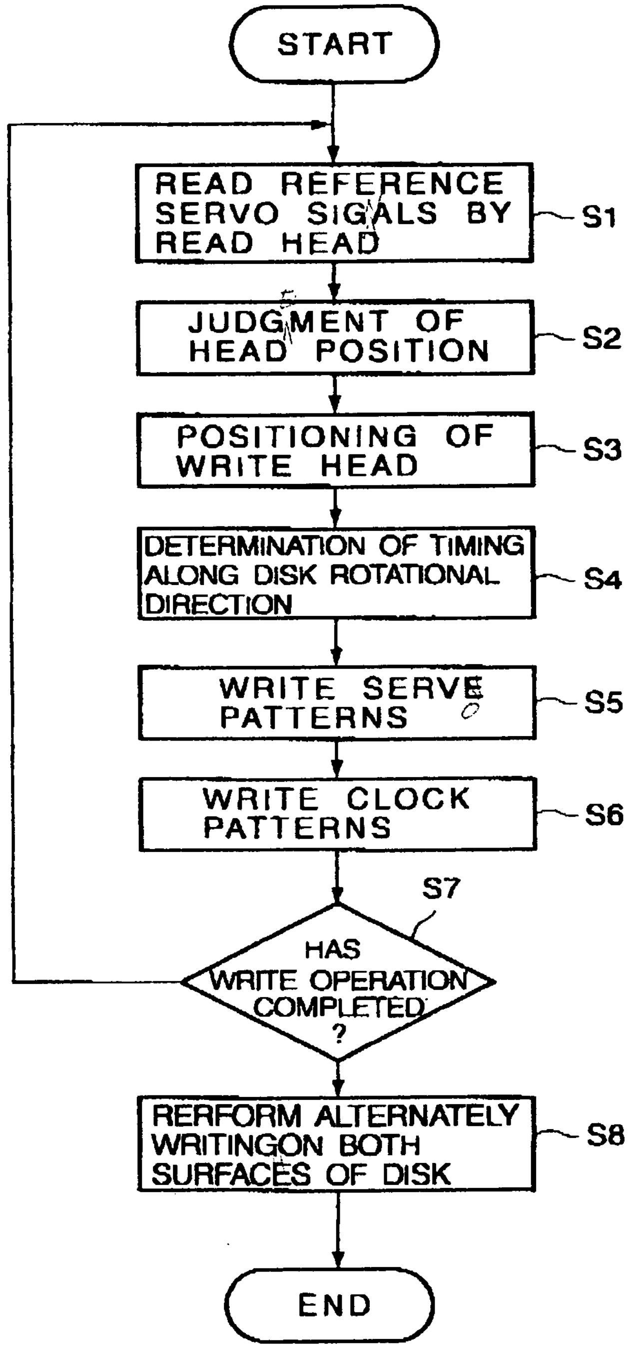
START
READ REFERENCE SERVO SIGALS BY READ HEAD
S1
JUDGMENT OF HEAD POSITION
S2
POSITIONING OF WRITE HEAD
S3
DETERMINATION OF TIMING ALONG DISK ROTATIONAL DIRECTION
S4
WRITE SERVE PATTERNS
S5
WRITE CLOCK PATTERNS
S6
S7
HAS WRITE OPERATION COMPLETED ?
RERFORM ALTERNATELY WRITINGON BOTH SURFACES OF DISK
S8
END

FIG.12